Research and Development as a Value Creating Asset*

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Abstract

As part of the revision to the 1993 System of National Accounts (SNA93), the way the UK treats research and development is going to change. Research and development (R&D) is no longer going to be treated as an intermediate input for businesses and current consumption for governments and Non-Profit Institutions; instead it will be treated as capital expenditure. The capitalisation of R&D requires a number of important steps. The first step is to determine the components of R&D expenditure to be included in the R&D capital stock and also translating R&D expenditure data in to an SNA compatible format. The next step is the construction of appropriate deflators, an issue created by the heterogeneity of R&D products. The final step requires the estimation of appropriate depreciation rates for R&D capital. This paper presents work on these three steps for the business sector and also some estimates of the productivity impact of R&D.

Keywords: R&D, Investment, National Accounts, Productivity, Depreciation

*This paper presents the current stage of an ongoing project. As such its content is work in progress and we would welcome comments and suggestions.

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1. Introduction

In the current environment of rapid technological change, Research and Development (R&D) has proven to be an important element of economic growth. R&D is considered one of a number of measures of innovation performance and various studies have shown that investment in R&D is an important source of productivity growth (for example Griliches, 1981). R&D investment reduces production costs, as inputs are more effectively transformed in to outputs, and it alters output characteristics, thereby providing new products to the marketplace (Bernstein and Mamuneas, 2004). As a result the promotion of investment in R&D has become a priority within the EU.

In Barcelona, 2002, EU heads of Government set a target for EU R&D to reach 3% of GDP by 2010, with two-thirds of this coming from businesses. As a result of this, many EU countries set domestic targets, including the UK. The UK government set a target of 2.5% of GDP by 2014 (total UK R&D currently stands at 1.78% of GDP, ONS 2006). In the scenario attached to the governments R&D target it envisages that business R&D will reach 1.7% of GDP with R&D in higher education and government making up the balance.

In 2004, expenditure on R&D in the UK totalled £21bn, an increase of 1% in cash terms from 2003. However, as a percentage of GDP the rate of R&D in the UK has been falling over the past three years from 1.86% in 2002 and 2003 to 1.78% of GDP in 2004 (ONS, 2006).

The official guidelines for collecting R&D data come from the OECD Frascati manual. The manual deals exclusively with the measurement of human and financial resources devoted to R&D, namely R&D ‘input’ data. It provides a platform for internationally comparable data on R&D. The manual describes R&D as ‘comprising creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications’.

The manual acknowledges three types of R&D activities: basic research, applied research and experimental development. Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view. Applied research is also original investigation undertaken in order to acquire new knowledge. It is however, directed primarily towards a specific practical aim or objective. Experimental development is systematic work, drawing on the existing knowledge gains from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed.

Although it is widely accepted that expenditure on R&D by firms is a means to improving their productivity via new processes and product innovations, it is not recorded by National Accounts in a way that reflects this. R&D is currently treated as an intermediate input for businesses and current consumption for government and non-profit institutions.

The Advisory expert group on National Accounts (after advice from Canberra II) have recommended that R&D is capitalised as part of the System of National Accounts (SNA93) revisions (due in 2008). Eight recommendations have been made:

1. The 1993 SNA should be changed to recognise the outputs of R&D assets, and the acquisition, disposal and depreciation of R&D fixed assets should be treated in the same way as other fixed assets.
2. In principle, freely available R&D should not be included as Capital formation, but in practice it may not be possible to exclude it. The assumption is that including freely available R&D would not lead to significant error.
3. The definition of an asset should be reviewed to ensure that it covers the assets of non-market producers adequately.
4. The definition of R&D given in the Frascati Manual (FM) should be adopted in the SNA.
5. The Frascati system provides the best means of deriving estimates of R&D statistics, principally Gross fixed Capital Formation (GFCF). However, there are shortcomings in the Frascati data and the Frascati Manual should be amended to better support the needs of the SNA.
6. Most R&D output is produced over several periods and the SNA recommendations for the production of other assets should apply. Most R&D production is on own account, which implies recording it as GFCF as it occurs under the current recommendations.
7. Detailed input price indexes, corresponding to the constituents of the estimates of R&D GFCF, should be used to derive constant price estimates of R&D output and GFCF.
8. Patented entities should no longer be recognised as assets in the system.

In preparation for revisions to the SNA relating to R&D, Eurostat have funded an ONS project to assess the practical and methodological issues involved in capitalising R&D in National Accounts. This paper presents the current state of this work and identifies areas where further work is needed. Section 2 provides a methodological overview, covering the estimation of R&D GFCF, estimation of R&D deflators and the estimation of depreciation rates for R&D capital. Section 3 describes the UK data sources on business expenditure on R&D and also other required sources that are available for implementing the methodology outlined in Section 2. Currently the focus is just on the business sector element of R&D. Section 4 presents estimates for the UK business sector based on applying the methodology outlined in Section 2 to the UK data described in Section 3. Section 5 looks at the contribution of R&D to productivity growth. Conclusions and future work are covered in section 6.

2. Methodological Overview

2.1. Methodological issues

2.1.1. Linking Tables: Linking Frascati based expenditure to SNA

In order to capitalise R&D we need to translate Frascati expenditure data into an SNA compatible format. The value of R&D that we want to capitalise within the SNA framework is gross output minus intermediate inputs. The first step involves converting Frascati sectors into SNA sectors. Robbins (2005) provides the following link table.

Table 1: Link table - Frascati sectors to SNA sectors

Frascati Manual	SNA
Business Enterprise Sector	Non-financial Corporations
	Financial Corporations
Government Sector	General Government Sector
Private non-profit sector	Non-profit institutions serving Households (NPISH)
Higher education sector	General Government
	NPISH
Abroad	Rest of the world

De Haan and van Horsten (2005) suggest three product groups to help translate GERD (gross expenditure in R&D) to SNA:

Market R&D – their value should be determined by estimated basic prices. Production costs should be used if reliable market prices are not available.

Non-market R&D – are by convention valued by the sum of production costs. They suggest that by convention all non-market output of goods and services is consumed by the government sector. They highlight that the sum of outlays as reflected by GERD is not consistent with the sum of production costs in accordance with National Account principles. They suggest replacing the figures on capital expenditure included in GERD with an estimation of COFC[2]. Robbins (2005) identifies R&D as a non-market good based on its producer, either government, universities or non-profit institutions.

Own Account – The SNA rule is to value own account production using market prices. When a suitable market price can not be used, the 'second best' option should be used i.e. the sum of the production costs.

In order to arrive at our gross output figure we need to sum intermediate consumption, capital services and net value added[3]. A bridge table between the Frascati manual and SNA data on R&D would include the following (Soli Peleg, Central Bureau of Statistics, Israel, 2006):

I. Output

A. Frascati manual GERD
1. **Plus** Acquisition of R&D to be used as input in R&D production
2. **Plus** Depreciation of Capital goods owned by R&D producers and used in R&D production
3. **Plus** Net Operating Surplus contained in R&D output measured at basic prices
4. **Plus** other taxes less other subsidies on production
5. **Minus** Capital Expenditures

B. R&D output by SNA93 definitions

[2] COFC represents the reduction in the value of the fixed asset used in production during the accounting period resulting from physical deterioration, normal obsolescence or normal accidental damage. (OECD manual: Measuring capital,2001).

[3] Net value added is the sum of compensation of employees, other taxes on production and imports less subsidies plus net operating surplus.

Equal to GERD + (1) + (2) + (3) + (4) – (5)

II. Data for preparation of Supply and Uses Tables
Exports and Imports of R&D

6. R&D exports
7. R&D imports

Not all the data implied by the above are available for R&D in the UK (Operating surplus, exports and imports of R&D output).Table 2 gives an indication of the UK data we do have available and the adjustments we need to make to come up with a satisfactory gross output figure. This table is based on linking work done by the BEA (Robbins, 2005).

Table 2: UK data availability

Non Financial Corporations	**Financial Corporations**	**General Government**	**NPISH**
BERD	BERD	GOVERD (HERD for public universities)	Non-profit expenditure on R&D (HERD for private universities)
Minus capital Expenditure for financial corporations	Minus capital Expenditure for non-financial corporations	Minus Capital expenditure including those for land and structures	Minus capital Expenditure by NPISH serving business
Plus Expenditure for NPISH serving business	Plus Expenditure for NPISH serving business	Minus Current expenditure for non-plant machinery and equipment, as well as purchased and own-account software (estimated with ratio of equipment and software to gross output)	Plus Capital services
Plus R&D purchased as an intermediate input to production of R&D in the corporate sector (includes cost of	Plus R&D purchased as an intermediate input to production of R&D in the corporate sector (includes cost of any purchased	Plus Capital services	N/A

any purchased R&D	R&D		
Minus Historical cost depreciation	Minus Historical cost depreciation	Minus Payments for trade in R&D services	N/A
Plus Capital services on structures, equipment and software owned by R&D performers and used to perform R&D in the UK	Plus Capital services on structures, equipment and software owned by R&D performers and used to perform R&D in the UK	N/A	N/A

2.1.2. Freely available R&D

In this paper we take these recommendations outlined in section 1 as given. However, recommendation two has an element of choice as to the way individual National Statistics offices choose to interpret it. The decision of whether or not to include freely available R&D as part of Gross Fixed Capital Formation (GFCF) has proven to be controversial. A key question we should be asking ourselves initially is what is freely available R&D?

The joint Canberra II/NESTI meeting in Berlin (May 2006) attempted to try and clarify this issue. It was suggested that freely available R&D be defined as R&D output that has been acquired with either no intention of gaining benefits for the originator (or members of its collective group) or with the sole purpose of giving the output to other units in an unrestricted way. Making copies of R&D output freely available does not exclude the original from being an asset providing the intended benefits to the owner are not diminished (Aspden, 2006).

The argument for including all freely available R&D as GFCF was largely based on the argument that R&D made freely available would be likely to be small and difficult to identify. However, this once again depends on what we adopt as freely available and how we separate it out. It is not as easy as saying all government, higher education and NPI R&D is freely available, because this is clearly not the case. Indeed if we did assume this was the case then freely available R&D would no longer be negligible for some countries. For instance in the UK these sectors accounted for nearly 30% of UK R&D.

For the purpose of this paper we are going to assume that we include freely disseminated R&D, largely because it is too difficult to separate it out.

We also argue the case that unsuccessful R&D is a cost of producing R&D and is therefore indirectly incorporated in to the market value of R&D assets given they are valued at cost. Therefore, unsuccessful R&D would not have an asset life independent of successful R&D in the National Accounts. This would see R&D being treated the same as mineral exploration, where it is viewed that the returns from the successes are sufficient overall to pay for the failures.

2.1.3. Potential for double counting

There is a potential problem with an overlap with computer software. The Frascati Manual identifies three types of capital expenditure:

1. Land and buildings
2. Instruments and equipment
3. Computer software

The UK BERD survey asks for data under land and buildings and plant and machinery and does not separate out software. Mantler and Peleg highlight two types of potential R&D software overlaps:

1. R&D may be performed with the aim of developing a software original
2. The development of software may be part of a R&D project

Mantler and Peleg also distinguish between two products:

1. An asset – the software – that can be used repeatedly in production
2. R&D that is a product in itself, whether regarded as an asset or as intermediate consumption

Contrary to this view de Haan and Van Horsten (2005) assume that R&D fully devoted to the development of a new software original, will generally constitute an inseparable part of the production process, with a single identifiable output. Their view and current SNA93 says that all R&D with the specific goal of developing a software original should be identified as software and not as R&D. When it is not possible to separate R&D software development within an R&D project then that software should not be recorded as a separate asset.

De Haan and Van Horsten (2005) agree with Mantler and Peleg accounting recommendations when software is developed as a supplementary tool. If it can be identified as such then the software should be identified as a separate asset and the consumption of fixed capital of this software should be part of the production costs of R&D output.

The main issue for the ONS is not so much double counting within the software industry, but the amount of R&D software being double counted within other industries. In BERD software development outside of the software industry is recorded under the product sold by the company. This software development (if classified as R&D by the company) will be included in their capital expenditure figures on the BERD form. However, ONS is likely to have already picked these figures up in its own-account software numbers, which in the future will be based on the total wage costs of labour working on own-account software production (see Chamberlain, Chesson, Clayton and Farooqui, 2006).

Whereas it will be relatively straight forward to compare the computer software industry figures from R&D and ICT surveys, the water is a little cloudier with regards to working out how much double counting has occurred for own-account software within non-computer orientated industries.

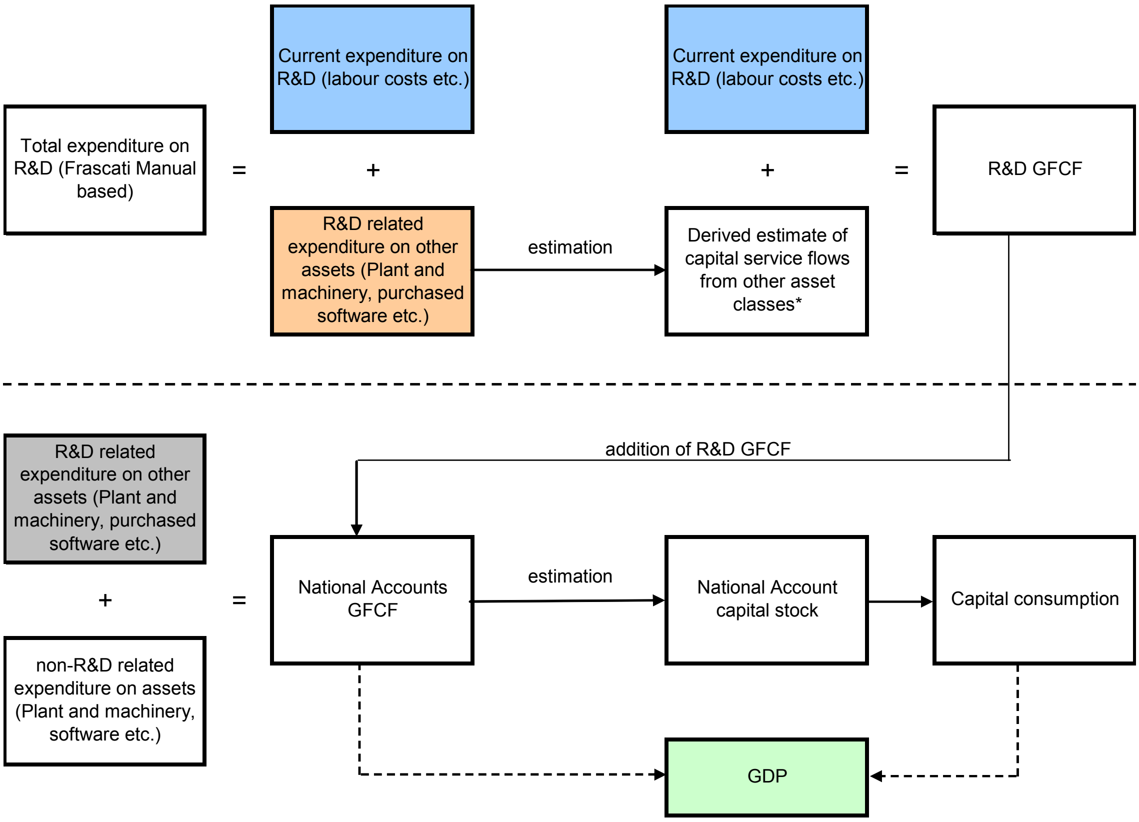
Another potential issue of double counting arises. Estimates from surveys collecting data on GFCF (CAPEX and ABI) will include some intellectual property as the present forms do not instruct respondents to exclude it. Therefore adding in the results of the R&D survey to National Accounts will potentially lead to double counting. Additionally not all expenditure by companies in the R&D industry will result in intellectual property. For example they also have to invest in furniture and fittings, computers etc. These numbers will be picked up not only in the R&D survey, but also within the ONS CAPEX and ABI surveys, so again double counting is likely to result.

Table B1 in the appendix however, lists the breakdown of expenditures per industry by salaries and wages, other, plant and machinery and land and buildings for 2002. They show that the issue of double counting is different across industries, but on the whole the expenditure split is largely biased towards salaries and wages rather than capital, hence the double counting issue may not in fact be that large. Charles Aspden (2006) suggests that all producers of capital products acquire capital to produce them and this type of double counting is part and parcel of the current SNA.

2.2 Current price GFCF

In order to estimate 'at cost' GFCF we need to make some adjustment to Frascati based expenditure data. Figure 1 below provides a diagrammatic representation of how we get from Frascati based total expenditure on R&D to a position where R&D is capitalised in the National Accounts. Figure 1 identifies that capitalising R&D will impact on total National Accounts GCFC and also capital consumption, with both these effects having an impact on GDP.

Figure 1: Capitalising R&D



* Can either be derived as consumption of fixed capital COFC (capital consumption) plus a normal return on capital used or direct capital services estimates

We identify three different methods to derive the estimate of capital service flows from other asset classes. This capital service flow is essentially an estimate of the input of the other capital (mostly tangible capital), used in the R&D process, to the R&D capital stock. In the first model, this input is proxied by consumption of fixed capital (COFC) plus an assumed return on those assets. In the second and third models, the capital service flow from the assets used in the R&D process is measured directly. One method uses rental rates, the other capital services growth rates.

Figure 1 highlights that there is possibly some double counting of the other asset classes (plant & machinery etc.) used in R&D. In figure 1 an estimated return on these assets is used to form part of R&D GFCF. Once we have R&D GFCF and added it to existing National Accounts GFCF we estimate a whole economy capital stock, from which we derive capital consumption to form part of GDP. The existing National Accounts GFCF will already include R&D related expenditure on other asset classes. This suggests that there is a case for excluding the R&D related expenditure on these other asset classes from the National Accounts GFCF (the grey box) or just taking R&D GFCF as current expenditure (just taking R&D GFCF as equal to the blue box).

The expenditure data we are interested in for our calculation of GFCF can be broken down in to two clear areas, intramural[4] (current and capital) and extramural[5]. Intramural expenditure can be split further between:

1. Current expenditure:

Salaries and wages: includes all overtime payments, bonuses, redundancies, commissions and holiday pay and should be gross.
Other: Purchases of goods and services from outside the unit, including overseas purchases, and scientific services should be included, provided no R&D is involved. Contractors employed on R&D projects are included here.

2. Capital expenditure:

Land and Buildings
Plant and Machinery

This should include annual gross expenditure on fixed assets used in R&D projects. Land and buildings comprises the acquisition of land and buildings, costs of major improvements and modifications or repairs.

We used the total extramural figure as an estimate for R&D purchased as an intermediate input. Hence we summed expenditure bought within and outside the UK. We, however, acknowledge the issue here with transfers versus purchases.

We have created three different estimates for R&D GFCF. They differ by the way in which we have estimated the services flow into R&D GFCF from the capital expenditure on Land & Buildings and Plant & Machinery used as part of the R&D process.

Method 1: Consumption of fixed capital (COFC) plus an assumed return

In method 1 our estimate of R&D GFCF is calculated as the following:

$$GFCF_t = \left(C_t + \sum_a I_{at} \right) - \sum_a I_{at} + \sum_a COFC_{at} + \sum_a R_{at}$$

Where C_t is current expenditure on R&D, I_{at} is current price investment in the asset type *a* being used in the R&D process[6], $COFC_{at}$ is the consumption of asset type *a* being used in the R&D production process and R_{at} is the assumed return on asset type *a* being used in the production process.

[4] Intramural expenditures are all expenditures for R&D performed within a statistical unit or sector of the economy during a specified period, whatever the source of funds.
[5] Extramural expenditures are the sums a unit, organisation or sector reports having paid or committed themselves to pay another unit, organisation or sector for the performance of R&D during a specified period. This includes acquisition of R&D performed by other units and grants given to others for performing R&D.
[6] Using UK data we can only identify two asset types here - land & buildings and plant & machinery.

COFC in time *t* for and asset of type *a* is given by the following.

$$COFC_{at} = K_{at} \cdot \delta_a$$

Where K_{at} is the net stock of asset type *a* at time *t* and δ_a is the rate of depreciation of asset *a*. To calculate a net stock for each asset type we used the perpetual inventory method (PIM). A geometric PIM was used to calculate net stock as follows.

$$K_{at} = \sum_{\tau=0}^{\infty} (1-\delta_{a,t-\tau})^{\tau} \cdot I_{a,t-\tau}$$

Where here *I* is constant price investment in asset *a*. In constructing this PIM we made the following assumption about the net capital stock in the initial year, assuming a steady state.

$$K_{a0} = I_{a0} / \delta_a$$

Finally for this model, we needed to calculate R_{at}. We used the Australian Bureau of Statistics assumption that the rate of return on capital used in the R&D process is 5%.

$$R_{at} = 0.05 \cdot K_{at}$$

Method 2: Capital services estimated using rentals

In method 2 our estimate of R&D GFCF is calculated as the following:

$$GFCF_t = \left(C_t + \sum_a I_{at} \right) - \sum_a I_{at} + \sum_a CS_{at}$$

Where variables are as defined above and CS_{at} is the capital service flow at time *t* from the asset type *a* being used as part of the R&D process[7].

For method 2 CS_{at} is calculated as the real level of capital services.

$$CS_{at} = K_{at} \cdot r_{at}$$

Where r_{at} is the rental for asset *a* at time *t*. The rental is calculated using the Hall-Jorgenson (Hall and Jorgenson, 1967) formula for the cost of capital in discrete time *t*.

$$r_{at} = T_{at}[\delta_a \cdot p_{at} + R_t\, p_{a,t-1} - (p_{at} - p_{a,t-1})]$$

[7] Capital services refer to the flow of productive services from the stock of capital. Capital services recognises that the same stock of capital may be used more or less intensively (capacity utilisation).

where p_{at} is the price of an asset of type *a* at time *t*, δ_a is the rate of depreciation, and R_t is the rate-of-return. T_{at} is the tax-adjustment factor which is given by the following:

$$T_{at} = \left[\frac{1 - u_t D_{at}}{1 - u_t} \right]$$

where u_t is the corporation tax rate and D_{at} is the present value of depreciation allowances as a proportion of the price of asset type *a*.

Method 3: Capital services estimated using capital services growth rates

In method 3 our estimate of R&D GFCF is calculated as the following:

$$GFCF_t = \left(C_t + \sum_a I_{at} \right) - \sum_a I_{at} + \sum_a CS_{at}$$

This is as in method 2. Here however CS_{at} is calculated using a different method. In the initial year the capital service input to R&D is estimated using the real level of capital services as in method 2.

$$CS_{a0} = K_{a0} \cdot r_{a0}$$

Subsequent years are calculated as follows.

$$CS_{at+1} = CS_{at} \cdot g_{at} \text{ for } t = 1, 2, \ldots$$

Where g_{at} is the growth rate of capital services for asset *a* at time *t*.[8]

2.3. Constant price GFCF - Volume estimates: Industry specific deflators

A suitable deflator is needed in order to convert current price R&D GFCF into constant price GFCF. If we want to look at the contribution of R&D expenditure to economic growth and productivity then we need to correct for inflation. Jankowski (1991) highlights the absence of relevant deflators, needed for investigating the links between R&D and other components of the innovation process.

The major problem associated with constructing a deflator for R&D is that R&D is a very heterogeneous product. By definition every project is different and hence will not command the same price in the market place. Given that the majority of R&D is carried out on own account, this makes it hard, if not impossible, to calculate a market price (output price). As a result the next best solution would appear to be the use of input prices.

[8] Capital services growth rates are a much more common output of statistical offices than estimated rental rates. UK capital services growth rates are published annually (see Wallis (2005)) but currently rentals are not.

The ONS has used input based indexes to estimate output volumes. These may well seem inappropriate, but there are many other areas within National Accounts where they are used when a better alternative is not available. We have calculated industry specific deflators for Business R&D and we began by identifying the expenditure areas on BERD that we were interested in:

Wages and salaries
Other current expenditure
Land and buildings
Plant and Machinery.

We calculate R&D cost components and their appropriate weights in order to calculate a simple weighted index and a divisia index. Cameron (1996) argues that a Divisia index is theoretically and empirically better at capturing changes in the cost of R&D than fixed weighted indices such as the Laspeyres or Paasche indices.

The following table indicates the data sources we used:

Table 3: Deflator data sources

R&D Component	**Proxied by**	**Source**
Wages and Salaries	Index of earnings of science and technology Professionals	ASHE
	Index of average earnings if technicians	ASHE
	Index of average earnings of Administrative occupations	
Other current (materials etc)	PPI (input) materials and fuels purchased by manufacturing excluding FBTP	PPI
Capital	Separate index for plant and machinery and land and buildings	National Accounts capital stock deflators

The UK BERD form asks for firms to breakdown their average employment on R&D (number of full time equivalents) in to three areas:

Scientists and Engineers: Includes Professional scientists or engineers engaged in the conception, or creation of new knowledge, products, methods and systems.

Technicians: Are qualified personnel who participate in R&D projects by performing scientific and technical tasks, normally under the supervision of professional scientists and engineers. They will usually have scientific or engineering qualifications.

Other: Supporting staff include skilled and unskilled craftsmen, secretarial and clerical staff participating in R&D projects or directly associated with such projects.

In order to obtain wage information for these three occupational areas we used data from the Annual Survey hours and Earnings (ASHE). From this dataset we were able to obtain data on gross weekly wages (based on April figures) for 33 industries across several SOC codes.

Because the SOC codes changed (from SOC90 to SOC2000) in 2002 we also had to match SOC90 and SOC2000 to make them as consistent as possible across our time horizon.

The following table highlights the codes we used for each:

Table 4: SOC codes

SOC90	**SOC2000**
21: Engineers and technologists	21: Science and technology professionals
30: Scientific technicians	31: Science and technology associate professionals
40: Admin/clerical officers and assistants in the civil and local govt	41: Administrative professionals
41: Numerical clerks and cashiers	4214: Company secretaries
45: Secretaries, PAs, typists, word process operators	4215: PAs and other secretaries
46: Receptionists, telephonists and related occupations	4216: Receptionists
49: Clerical and secretarial occupations	4217: Typists

We merged together the admin codes for each SOC to produce one weekly wage figure as proxy wages for ‘other’ on the BERD form . For example for SOC90 we merged 40, 41, 45, 46 and 49 to give us one average weekly wage for each of the 33 industries. The same was done for SOC2000 i.e. we merged 41, 4214, 4215, 4216 and 4217 to produce one broad admin weekly wage. We were able to obtain data from 1997-2004 across the thirty three industries covered by BERD for the following three areas:

1. Science and technology Professionals
2. Technicians
3. Administrative occupations

We used these as proxy wage estimates for the three employment sectors defined on the BERD form, namely 1. as a proxy for Scientists and engineers, 2. as a proxy for technicians and 3. as a proxy for other.

For all the industries bar two we were able to obtain information. However for sectors A (agriculture, forestry and fishing) and X (recycling), the small sample sizes made the information disclosive. For these two industries we used wage data that represented the entire sector and not the three specific occupational areas we were after. Hence for A and X we used industry aggregate weekly gross wages.

We used a simple weighting technique to create our initial index and then calculated a divisia index to see if there was much difference. We choose 2000 as our base year (making it consistent with our other indices).

Initially a price index was calculated for each of the three employment areas; scientists, technicians and other and then the weights were applied to these indices:

$$W_s = \frac{E_s}{E_T}\,;\; W_t = \frac{E_t}{E_T}\,;\; W_o = \frac{E_o}{E_T}$$

Where:

W_s : Weight for scientists and engineers
W_t : Weight for technicians
W_o : Weight for 'other'
E_T : Total Frascati based expenditure on salaries and wages
E_s : Frascati based expenditure on scientists and engineers
E_t : Frascati based expenditure on technicians
E_o : Frascati based expenditure on 'other'

An aggregate index for salaries and wages was then calculated as:

$$P_s W_s + P_t W_t + P_o W_o \quad /100$$

For current expenditure we were unable to create an industry specific index due to data restrictions. We used a PPI input index as a proxy, namely PPI materials and fuels purchased by manufacturers excluding FBTP. On the capital side, we were able to use deflators already provided by National Accounts.

We then calculated a aggregate R&D index for each of the thirty three industries represented in BERD, applying the same methodology as above. Each index for salaries and wages, current other, plant and machinery and land and buildings was multiplied by its relevant weight, summed and divided by one hundred.

2.3.1. Lag times

It takes time to complete an R&D project and while work continues there is an accumulation of work in progress in inventories. Aspden (2005) notes that in concept, that once the project is complete the inventory should be run down and transferred to fixed capital formation.

Pakes and Shankerman (1979) note that there are two types of lag.

- Gestation lag is the time taken to undertake the R&D project

- Application lag is the time taken from completion of the project to its initial commercial use.

They suggest that the sum of gestation and application lags may range from 1.5 to 2.5 years. De Haan and van Horsten (2005) suggest the implication of such lags is that R&D output is initially recorded as work in progress i.e. changes in inventories. The completed R&D project is then recorded as GFCF when it is finished in the subsequent year, counterbalanced by negative withdrawals from inventories.

The BEA (1994) notes that survey based research found that gestation lags range from one to two years and the application lags range from less than one year to more than two years. For the purpose of deriving capital formation of R&D only (half) the gestation lag needs to be considered and the BEA used a one year lag.

Aspden (2005) suggests that once a quantum of knowledge has been gained then it can be said there was fixed capital formation. This implies that you do not necessarily have to wait until the project has been completed before GFCF is recognised. This line of argument implies that R&D output need not be very long in inventory before it can be legitimately viewed as an asset that contributes to further R&D production or some other output.

There are a number of assets that require a number of accounting periods to be produced e.g. large construction projects. The bulk is undertaken on own account, which implies recording it as GFCF as it occurs. That which is intended to be sold should be recorded as work in progress of the producer (note that SNA 93 recommendations on this regard are subject to review by the Canberra II group as part of the issue "Classification and terminology of non-financial assets").

2.4 Depreciation rates

In calculating an R&D stock, evidence supports the use of the Perpetual Inventory Method (PIM). The gross stock of R&D would be a measure of the cumulative value of past investment still in existence. Whilst the net capital stock would be equal to the gross stock less the accumulated depreciation on assets in the gross stock. Depreciation rates can be based on asset lives or they can be deduced using econometric studies of new and second-hand asset prices.

Whereas some research treats R&D as a permanent part of the capital stock once added, the consensus thinking is that once R&D capital has entered the capital stock it is gradually removed by depreciation (consumption of fixed capital).

The empirical evidence on depreciation rates for R&D assets is limited. The research that has been carried out has either taken on estimating depreciation rates using econometric models (for example Bernstein and Mamuneas) or using a patent renewal method (for example Pakes and Schankerman). The little evidence that has emerged from both types of analysis has on the whole produced a common message that industrial knowledge depreciates faster than physical capital. Mansfield (1979), Pakes and Shankerman (1978,1984) suggest there is little knowledge capital left after ten years. Bernstein and Mamuneas (2004) estimate that R&D capital depreciates at 2 to 7 times that rate of physical capital.

Depreciation rates reflect technical efficiency and indicate the productiveness of 'old' capital required to generate the same level of services as 'new' capital (Jorgenson, 1989 and Hulten and Wykoff, 1996). The growth of R&D capital depends on its 'economically useful life'. If the depreciation rate increases, then more resources need to be used in knowledge creation in order to maintain a constant knowledge outcome. This re-allocation of resources would raise the opportunity cost of R&D, and ceteris paribus, reduce the rate of knowledge creation. Hence it is important to estimate an R&D depreciation rate given it is a critical component for the measurement of R&D capital (Bernstein and Mamuneas 2004).

Bernstein and Mamuneas (2004) consider R&D depreciation within the context of intertemporal cost minimisation, where depreciation rates are estimated simultaneously with other parameters characterising the overall structure of production. They characterise R&D depreciation as a geometric or declining balance form[9]. The justification for this comes from a series of papers by Griliches (1979, 1990 and 1995). Griliches gives two justifications for this:

1. There is approximately a contemporaneous link between R&D and the services emanating from this investment through innovation and invention
2. Typically innovation and invention are short-lived, and replaced at a rapid rate

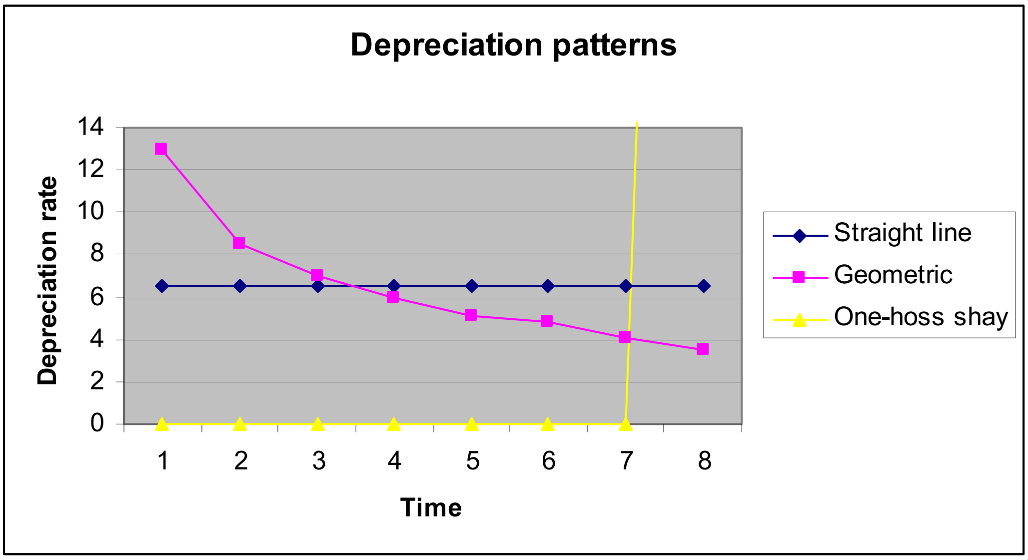
These imply that efficiency declines relatively faster in the early part of the service life of R&D investment, and therefore R&D depreciation approximates declining balance.

The BEA (1994) in the production of R&D satellite uses the PIM with uniform average service lives, straight-line depreciation and a bell-shaped distribution within each vintage of capital to determine discards (Winfrey). They acknowledged that geometric depreciation is typically used for R&D studies, with a rate of 11% the midpoint of a range published by academic researchers. Hence, although the BEA uses straight-line PIM for fixed tangible capital, they chose an average service life for R&D capital that yielded a net stock most comparable to a net stock from a geometric depreciation rate of 11%: an eighteen year service life yielded the closest match.

The easiest way to look at depreciation rates is graphically. The following graph highlights, straight-line, geometric and one-hoss shay (light-bulb) depreciation rate patterns:

[9] A Geometric pattern is a specific type of accelerated pattern. An accelerated pattern assumes higher £ depreciation in the early years of an assets service life than in the later years. This is in comparison to a straight-line depreciation pattern that sees equal £ depreciation over the life of the asset.

Figure 2: Depreciation patterns



The econometric results from Bernstein and Maumuneas (2004) estimate the following depreciation rates: 18% for Sic 28 (Chemical products), 26% for Sic 35 (nonelectrical machinery), 29% for Sic 36 (electrical products) and 21% for Sic 37 (transportation equipment). These imply that R&D capital depreciates in about three to five years.

Nadiri and Prucha (1996) estimate a depreciation rate of 12% for the US manufacturing sector (geometric depreciation rates). They estimated a model of factor demand that allowed for estimating jointly the depreciation rates of both physical and R&D capital for the US total manufacturing sector. Their 12% estimate of depreciation is very close to the ad hoc assumption usually used as a starting point in most PIM (15%). They used only gross investment data to generate estimates of the depreciation rates as well as consistent series for the stocks of R&D capital. The twelve percent estimate is not too dissimilar to studies that use R&D capital stocks as an input in the production function, Griliches (1980) and Bernstein and Nadiri (1988, 1991).

Other econometric estimates for depreciation rates have produced the following results:

Table 5: Empirical Depreciation estimates

US sectors	Baruch and Sougiannis (1999)	Ballester, Garcia-Ayuso and Livnat (2004)
Chemicals and Pharmaceuticals	5-16%	12%
Machinery and Computers	8-19%	17%
Electrical and Electronics	4-20%	18%
Transportation	7-17%	20%
Scientific Instruments	13-24%	15%
Overall aggregate industries	11-20%	n/a

On average the estimations for depreciation rates of R&D stock range from around 10-25%. This corresponds to an average service life of about 5-10 years.

We are proposing to estimate a depreciation rate for the whole economy using econometric methods. The method will be to look at the impact past R&D has on productivity (Gross value added at market prices) to get some idea of the rate of depreciation. That is, if R&D done five years ago has, on average, zero impact on value added today then we can insinuate the life length mean of R&D as being 5. We estimated the following:

$$\Delta GVA_t = \sum_{s=1...t} \alpha_s G_{t-s}$$

Where:

$\Delta GVA :_t$ Change in GVA from t to t-1
G_t : GFCF (investment)

We recognise that this is a very crude method and that the equation suffers from various specification issues, most notably omitted variable bias, but this is by no means a chosen specification, it is just an early investigation into a possible approach. We plan to develop this approach further as part of our next stage of work.

Our preliminary results are based in a panel of industry data for the period 1998-2003. From this panel we estimate a whole economy depreciation rate. In future we want to use a firm level panel to estimate industry specific deprecation rates. Table 6 show the results of this initial simple regression.

Table 6: Regression results

Gva_diff	**Coefficient**	**Standard error**	**t**
L1	-0.770473	7.516772	-0.01
L2	-18.89507	10.71141	-1.76
L3	42.80761	10.53161	4.06
L4	-26.19576	10.39732	-2.52
L5	2.838254	8.741311	0.32

These results suggest a life length mean for UK R&D of 5 years. The insignificance of the L1 and L2 combined with the insignificance of L5 also suggests that assuming a geometric depreciation rate for the UK may not be appropriate. The insignificance of L5 suggests a 'one-hoss shay' approach may be more appropriate, but that does not account for the insignificance of the coefficients in the earlier years.

If we assume a declining balance rate of 2 and use our formula for depreciation discussed already (R/T), this implies a depreciation rate for UK R&D of 40%, a rate much higher than those rates presented in the empirical studies discussed above. Clearly we do not place much weight on this result but it does suggest that the approach we have taken could provide sensible estimates of depreciation for R&D capital following further development.

3. UK data sources

3.1. Business Enterprise Research and Development (BERD)

The BERD is an annual survey designed to measure R&D expenditure and employment in the UK. Since 1995, the BERD survey has used a stratified random sample, stratified by Product Group and employment sizebands, where sizeband 1 (400+) is sampled 1:1, sizeband 2 (100-399) is sampled roughly 1:5 and sizeband 3 (0-99) being sampled roughly 1:20. These sampling fractions were reduced in 1998 as 400 more forms were made available for sampling.

In the first stage of the sampling procedure the largest 400 firms are chosen and in 2003's survey that corresponded to those enterprises doing more than £2.6m of R&D. These companies have either been identified from previous returns or from one of the other data sources. These 400 firms are then sent a long form.

There are a number of sources that contribute towards the sampling frame for the BERD. The ABI business survey asks a filter question about whether or not a firm engages in R&D. The DTI and Scottish executive provide ONS with R&D information on companies. Finally, the press is used to add to the sampling frame. The sampling frame covers all industries.

For those firms not receiving a long form, they are broken down in to the remaining two employment sizebands mentioned above. Enterprises are then selected randomly from each size band using the sampling fractions applicable to that band. Those identified are then sent a short form.

For non-selected firms, data is imputed on the basis that these enterprises have the same R&D to employment ratio as selected reporting units in their class.

Imputational Procedure:

Data for non-selected reporting units is imputed in the following way. Let E_I denote company employment (held on the IDBR for all reporting units in both surveys) and X_I denote a certain variable such as intramural R&D, where i indexes reporting units. The imputation is as follows:

1. The ratio $\frac{X_{IJ}}{E_{IJ}}$ is calculated for all selected observations in a given cell j, outliers are discarded.
2. The mean of this ratio is calculated for each cell j as

$$\frac{\sum_{i=1}^{nJ} \frac{X_{ij}}{E_{ij}}}{N_j}$$

3. This ratio is multiplied by company employment of non-selected reporting units to derive an estimate

$$\hat{X}_{ij} = E_{ij} * \frac{\sum_{i=1}^{nJ} \frac{X_{ij}}{E_{ij}}}{N_j}$$

of the variable X for non-selected reporting units in that cell.

3.2. Annual Respondent Database (ARD)

The ARD is constructed from a compulsory business survey. Until 1997 it was created out of the ACOP and ACOC (Annual Censuses of Production and Construction); these were combined into the ABI (Annual Business Inquiry) in 1998. To create the ARD, the other surveys are converted into a single consistent format linked by the IDBR references over time.

The data prior to 1998 cover the vast majority of production and construction activities (construction from 1993 only), but from 1997 the ABI also incorporates six other previous surveys covering distribution and other service activities. Hence from 1997 data on services are stored on the ARD. This increased coverage is reflected in the number of individual business contributors to the ARD rising from approximately 15,000 for 1980 to 1996 to approximately 50,000 for 1997/98 and to over 70,000 for 1999.

The businesses selected for the surveys have been drawn since 1994 from the ONS Inter-departmental Business Register (IDBR). The IDBR covers about 98% of business activity (by turnover) in Great Britain. Each year a stratified sample is drawn for the ABI and thus the data stored on the ARD is from business respondents returning the questionnaires that are sent out by the ONS.

The ABI is collected in two parts: ABI(1) is an employment record, collected as soon as possible after 12th December. ABI(2) is financial information, which may be submitted up to twelve months after the financial year end.

The proportion of businesses sampled varies with the size of the firm (in terms of employment). The ABI is a sample of smaller firms, but a census of larger ones. The ABI follows the ‘Osmotherly’ rules; if a small firm (fewer than ten employees) is sampled once, it is not sampled again for at least three years, for any survey. Since 1998 the sampling fractions have been as so:

<10: 0.25%
10-99: 0.5%
100-249: All or <=0.5 (varies by industry)
250 or more: All

Smaller firms may receive a "short form". These do not require detailed breakdowns of totals. Hence for certain variables the values may be imputed from third party sources or estimated rather than returned by respondents.

3.3. National Accounts Data

We obtained data from National Accounts on life length means and deflators.

The nature of the BERD data means that that the data can be split in to thirty-three product groups. However, this is not entirely consistent with National Accounts. Hence we needed to carry out some matching. The easiest way was to match National Accounts codes (CDID) to SIC codes and then round up to the broader product group level. Within any product group we have a number of SIC codes covering various different areas within that industry (see table 2 in the appendix). For land and buildings it was evident that the SIC codes within each product group tended to have the same CDID codes, hence the same deflators and life length means.

However, this was not the case for plant and machinery. It was evident that the SIC codes within certain product group codes had different CDID codes and hence we had multiple deflators and life length means within the product group. Therefore, we had to make some adjustments. We calculated the ratio of plm expenditure for each relevant SIC within the product group compared to total expenditure for that product group. We then weighted the life length means or deflators with these ratios to give us one life length mean and deflator for each of the 33 product groups:

Llm*P/100

Where:

Llm: Life length mean
P: Ratio of plm expenditure per Sic to total expenditure

Once we had the life length means for each industry we could calculate the depreciation rates for land and buildings and plant and machinery. The depreciation rate δ is calculated using the following equation

$$\delta = R / \overline{T}$$

where R is called the 'declining balance rate' and $\overline{T}$ is the life-length mean. R will differ across asset types. When $R=2$, as it does for intangibles, we have what is referred to as the 'double declining balance' method.

3.4. Capital Services Data

These estimates of capital services growth and rentals are based on Wallis (2005).

4. UK Estimates

4.1. Business Investment in R&D

The following table highlights our estimates for GFCF using our three different methodologies and compares them with the current R&D expenditure based measure as published in ONS (2006), 'Research and Development in UK Businesses (MA14). Table 7 shows that all 3 methods give GFCF above the MA14 estimate of total R&D expenditure. This means that the flow from the other capital assets being used as part of the R&D process, plant & machinery and land & building, is greater than the expenditure on these assets. This reflects the fact that investment in the stock of these assets is greater that the depreciation of the stock i.e. there is an increasing stock of other assets that are being used in the R&D process.

The main thing to note from the table is that the results from the three methods are quite similar. This means that despite methods 2 and 3 being preferable on theoretical grounds, as they directly measure capital services flows, using method 1 would give robust estimates. It is expected that some countries would not have the required capital services data to implement methods 2 or 3.

Table 7: Business investment in R&D, £bn

Year	MA14: Total R&D expenditure	Method 1	Method 2	Method 3
2003	13.7	15.1	15.1	14.6
2002	13.1	14.9	15	14.5
2001	12.3	13.5	13.4	13.1
2000	11.5	12.4	12.5	12.1
1999	11.3	12.5	12.7	12.3
1998	10.1	10.9	11.1	10.8
1997	9.5	11.3	10.4	11.2

Source: MA14 (ONS, 2006), methods 1, 2 and 3 authors own calculations.

We ran the PIM to create our business sector R&D capital stock estimates using two different depreciation rates. The table blow shows the results from using an average from empirical studies of 15%.

Table 8: Business R&D capital stock, 15% depreciation, £bn

Year	Method 1	Method 2	Method 3
2003	64.2	64.5	62.7
2002	57.8	58	56.7
2001	50.4	50.1	49.6
2000	43.5	43.9	42.9
1999	36.7	37	36.3
1998	28.4	28.7	28.2
1997	20.5	20.6	20.5
1996	12	12.1	12.1

Source: Authors own calculations.

The following table shows estimates of UK business sector R&D capital stock using our 40% depreciation rate.

Table 9: Business R&D capital stock, 40% depreciation, £bn

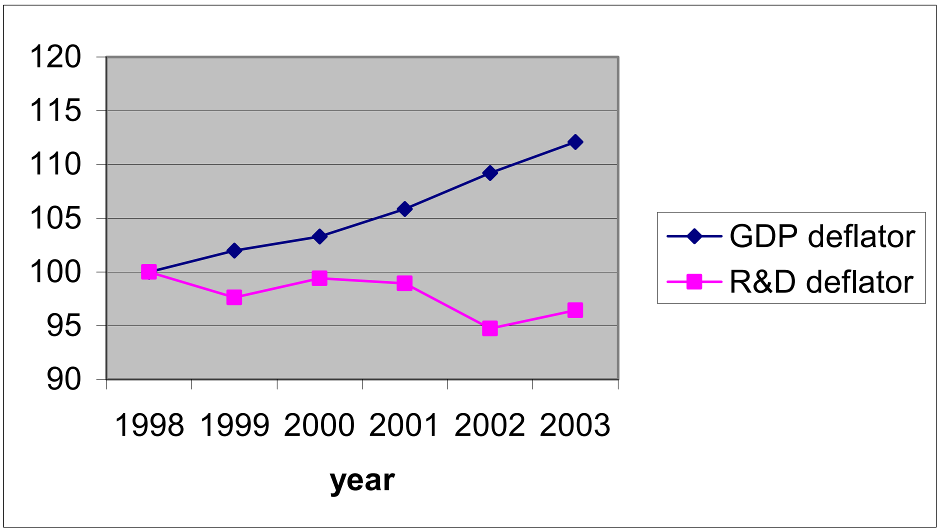
Year	Method 1	Method 2	Method 3
2003	34.9	35.1	33.9
2002	33.1	33.3	32.3
2001	30.4	30.4	29.8
2000	28.3	28.5	27.9
1999	26.5	26.7	26.1
1998	23.2	23.5	23.1
1997	20.5	20.7	20.5
1996	17.0	17.1	17.1

Source: Authors own calculations.

4.2. R&D Deflator

Figure 3 below shows our estimated deflator for business sector R&D against the UK GDP deflator. It is clear that the two differ quite a bit. This suggests that the GDP deflator is not a good proxy.

Figure 3: GDP deflator and estimated R&D deflator, 1998=100



5. Contribution of R&D to productivity growth

After capitalising R&D it was important to look at the impact this would have on productivity. We wanted to assess how R&D worked as a capital investment at firm level, showing the 'return' to R&D investment in production function.

We created a panel data set, merging BERD data and ARD data from 1998-2003. This gave us a panel dataset containing 16,095 observations. 1460 of which were long form, 4960 short form and 9311 unselected firms.

We started by using a model common to a lot of empirical studies of the R&D contributions to productivity growth, an extended Cobb-Douglas production function including time trends and firm specific effects:

$$Y_{it} = AN^{\alpha 1}K^{\alpha 2}R^{\alpha 3}E^{\beta_T}$$

Where Y is some measure of value added, K is capital, N is labour, R is R&D, A is a parameter representing spillovers (proxied by the sum of R&D within the industry) and E is the error term.

In log form, with the addition of an interactive dummy for the services industry $(\alpha 4)$:

$$y_{it} = a + \alpha 1 n_{it} + \alpha 2 k_{it} + \alpha 3 r_{it} + \alpha 4 r_{it} + e_{it}$$

Where, e^{it} is the error term and *a* is the impact of external knowledge on the firm's productivity.

We have the choice of assuming constant returns to scale (CRS) in the Cobb-Douglas production function: $\alpha 1 + \alpha 2 + \alpha 3 = 1$ or not.

$$\mathrm{y}_{it} - \mathrm{n}_{it} = \mathrm{a} + \lambda t + (\phi - 1)\mathrm{n}_{it} + \alpha 2(k_{it} - \mathrm{n}_{it}) + \alpha 3(r_{it} - \mathrm{n}_{it}) + \mathrm{e}_{it}$$

Where $\alpha 1 + \alpha 2 + \alpha 3 = \phi$. If there is CRS then $\phi = 1$ and $1 - \phi = 0$.

There were several estimation issues that we faced with our preliminary estimates. Firstly there is the double counting issue. R&D expenditures used to calculate the firm level capital stock will include expenditures on labour and capital. It is likely that these expenditures will already have been included in our other explanatory variables, N and K. Rogers (2005) highlights this as an issue. Schankerman suggests that the problem will bias R&D coefficients downwards.

Our preliminary results estimate an elasticity of 0.07%. The estimate of 0.07% implies a 10% increase in BERD is associated with an increase in productivity of 0.7%. That is the elasticity estimates the percentage change in productivity for a percentage change in BERD. Our analysis also finds that there is an average difference between the impact of services and manufacturing on productivity. That is, services are on average more productive. However, we find that this 'higher' productivity impact for services is not to do with our measures of R&D capital stock (our interactive term was not significant).

6. Conclusions and Future Work

We have addressed several issues involved in the capitalisation of R&D for the UK National Accounts. We have taken the eight recommendations from the Canberra II group as given. Their second recommendation regarding the treatment of freely available R&D provides an element of choice and we have decided to include all freely available R&D in our estimates given the difficulty faced in removing it. Although we acknowledge that this area needs more discussion.

The first issue we addressed was calculating R&D GFCF. We presented three separate methods; the first involved calculating COFC and a normal rate of return, the second estimated capital services using rentals and the third estimated capital services using capital service growth rates. The results presented in table A2 show that there is little difference between the three methods and hence for those countries that may not be able to produce capital services estimates, GFCF estimated using COFC and a normal rate of return should be equally satisfactory.

Estimating an R&D specific deflator bought a number of issues to the fore. R&D is a very heterogeneous product by definition and hence each project will not command the same price in the market place. Hence this makes it virtually impossible to calculate an output based deflator. As a result we calculated an index using input prices. We produced industry specific deflators which showed significant differences between industries (see tables B1a to B1g in the Appendix). Our estimate for a business sector R&D specific deflator showed that the use of a GDP deflator in R&D capitalisation calculations may not be an accurate proxy.

In calculating an R&D capital stock we used the PIM. This required an estimation of an R&D specific depreciation rate. We were slightly constrained by time horizon of UK microdata (starting in 1997), however, we still estimated a whole economy depreciation rate using econometric methods. Our preliminary results imply a depreciation rate for UK business R&D of 40%. This is a somewhat higher rate of return to UK R&D than that estimated in empirical studies to date. However, these results are only preliminary and we need to carry out more econometric analysis on this issue.

Our productivity analysis is very much in its preliminary stages. Using firm level data we have estimated an elasticity of 0.07%. This implies a 10% increase in BERD is associated with an increase in productivity of 0.7%. We intend to continue our analysis in this area, paying more attention to our measure of the spillover effect. Future analysis will also take on a more macro approach, looking at aggregate productivity growth in order to estimate GDP per worker.

The most notable thing that comes out of our work so far is that not only is calculating depreciation rates the most difficult element but also that estimated R&D capital stock is much more sensitive to different depreciation rates than it is to changes in the way we calculate R&D GFCF and our R&D deflators.

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Appendix A

Table A1: Expenditure weights 2002

	S&W	Materials	P&M	L&B
A	41.63557	36.74826	6.880666	14.7355
AA	43.40871	52.40227	2.65218	1.536837
AB	7.147399	92.85223	0.000243	0.000133
AC	44.9062	53.43642	1.512183	0.145185
AD	51.27462	39.0529	3.73661	5.935865
AE	56.98972	37.41522	4.467709	1.127353
AF	44.00825	45.71552	8.050952	2.225277
AG	37.0538	48.3575	10.78102	3.807672
B	49.61785	44.05784	5.917051	0.407261
C	42.96103	44.93606	10.90548	1.197427
D	54.42524	25.2912	20.09991	0.183655
E	35.10495	56.53734	1.223142	7.134569
F	32.41785	37.17924	2.010469	28.39244
G	50.88356	40.044	6.922776	2.149665
H	44.65239	47.82876	6.423893	1.094952
I	28.7515	41.25646	24.06476	5.927285
J	46.59167	41.39086	11.73955	0.277917
K	60.73153	38.03753	1.230929	n/a
L	51.62009	45.03441	3.344144	0.00136
M	41.01254	50.08486	5.331685	3.570923
N	52.31301	43.35789	2.202815	2.126285
O	45.21375	49.89598	4.808517	0.081759
P	49.65067	44.45918	5.64629	0.243866
Q	47.42692	47.11893	4.948197	0.50596
R	44.65239	47.82876	6.423893	1.094952
S	47.85854	48.49076	3.228828	0.421865
T	8.918672	90.86018	0.189378	0.031762
U	41.76564	58.21868	0.015682	n/a
V	33.43279	60.4787	6.085865	0.002645
W	54.4636	32.38409	6.648566	6.503738
X	61.76471	31.95187	6.283423	n/a
Y	53.47665	42.14273	2.490982	1.889632
Z	56.5303	37.73611	5.726839	0.006752

Table A2. BERD product groups and SIC codes

Product Group Code	**Description**	**SIC 2003**
A	Agriculture, Hunting and Forestry, Fishing	01, 02, 05
AA	Wholesale and retail trade; Repair of motor vehicles, motorcycles and personal household goods; Hotels and restaurants	50, 51, 52, 55
AB	Transport and Storage	60, 61, 62, 63
AC	Post and Telecommunications	64
AD	Financial Intermediation; Real estate; Legal; Market Research; Business and Management consultancy; Advertising; Architectural and engineering activities and related technical consultancy; Technical testing and analysis	65, 66, 67, 70, 71, 74
AE	Compute and related activities, including software consultancy and supply	72
AF	R&D services	73
AG	Public administration	75 to 99
B	Extractive Industries including solids, liquids and gases	10, 11, 12, 13, 14
C	Food products and beverages; Manufacture of tobacco products	15, 16
D	Textiles and clothes; Tanning and dressing of leather; Manufacture of luggage, handbags, saddlery, harness and footwear	17, 18, 19
E	Wood and products of wood and cork; manufacture of articles of straw and plaiting materials. Pulp, paper and paper products; Publishing, printing and reproduction of recorded media	20, 21, 22
F	Refined petroleum products and coke oven	23

	products; Processing of nuclear fuel	
G	Chemicals, chemical products and man-made fibres (excluding manufacture of pharmaceutical, medical chemicals and botanical products)	24 (excluding 24.4)
H	Pharmaceuticals, medical chemicals and botanical products	24.4
I	Rubber and plastic products	25
J	Other non-metallic mineral products	26
K	Basic iron and steel and ferro-alloys; Manufacture of tubes; casting of iron and steel	27.1, 27.2, 27.3, 27.51, 27.52
L	Basic precious and non-ferrous metals; Casting of light metal; Casting of other non-ferrous metal	27.4, 27.53, 27.54
M	Fabricated metal products, except machinery and equipment	28
N	Machinery and equipment not elsewhere classified	29
O	Office machinery and computers	30
P	Electrical machinery and apparatus not elsewhere classified	31
Q	Radio, television and communications equipment apparatus	32
R	Medical precision and optical instruments, and appliances for measuring, checking, testing, navigating and other purposes	33
S	Motor vehicles, trailers and semi-trailers; Parts and accessories for motor vehicles and their engines	34
T	Railway and tramway locomotive and rolling	35.2, 35.4, 35.5

	stock; Motorcycles and bicycles	
U	Building and repairing of ships and boats	35.1
V	Aircraft and spacecraft	35.3
W	Furniture; Jewellery and related articles; Musical Instruments; Sports goods; Games and toys; Miscellaneous manufacturing not elsewhere classified	36
X	Recovered secondary raw materials, recycling	37
Y	Electricity, gas and water supply	40, 41
Z	Construction	45

Appendix B

Table B1a: GDP and R&D deflators

	Price Indices	
Year	GDP	R&D
1998	100	100
1999	102	97.6
2000	103.3	99.4
2001	105.9	98.9
2002	109.2	94.7
2003	112.1	96.4

Table B1b: R&D industry level deflators

Industry						
year	A	AA	AB	AC	AD	AE
1997	95.7	100.7	98.4	101.3	100.8	103.2
1998	94.9	97.4	99.8	99.1	98.5	101.5
1999	96.4	98.6	97	96.6	96.9	100.9
2000	100	100	100	100	100	100
2001	99.1	102.7	99	99	101.2	107.1
2002	104.2	100	94.4	99.3	104	109.1
2003	105.2	101	95.5	98.8	103.2	112.9

Table B1c: R&D industry level deflators

Industry						
year	AF	AG	B	C	D	E
1997	99.2	104.2	99.2	97.5	102.3	98.2
1998	96.6	100.2	104.7	101.7	106.6	96.3
1999	95.2	97.9	102.2	101	96.2	93.7
2000	100	100	100	100	100	100
2001	99.4	99.4	104.4	101.7	111	96.9
2002	97.6	95.5	107.3	102.5	103.6	95.2
2003	100.2	97.5	101.4	102.8	99.3	96.5

Table B1d: R&D industry level deflators

Industry						
year	F	G	H	I	J	K
1997	97.7	99.8	100.3	96.7	95.3	94.2
1998	94.5	97.5	100	95.8	95.4	97.6
1999	98.1	97.9	99.2	96.6	96.9	95
2000	100	100	100	100	100	100
2001	101.8	101.5	99.7	100.5	100.8	103.3
2002	102.4	100.8	100.3	101.5	103.2	110
2003	102.4	98.6	105.6	101.9	104.5	107

Table B1e: R&D industry level deflators

Industry						
year	L	M	N	O	P	Q
1997	93.8	105.2	99.2	103	98.1	99.5
1998	95.4	103.2	99.4	99.9	99.2	98.4
1999	96.1	97.4	99.2	100	98.7	97
2000	100	100	100	100	100	100
2001	101.8	103.5	101	104.2	101.4	105.5
2002	95.2	101.1	102.6	102.2	101.4	104.4
2003	96.3	101.6	100.9	103.3	105	108.3

Table B1f: R&D industry level deflators

Industry						
year	R	S	T	U	V	W
1997	97	99.2	105.9	94.3	97.5	98.6
1998	95.7	97.8	104.9	95.4	97.1	90.9
1999	94.3	96.7	99.1	97.8	95.7	91.3
2000	100	100	100	100	100	100
2001	102.5	105.3	101.4	104.1	99	100.9
2002	102.9	104.5	97.1	101.5	95.5	103.7
2003	105.1	109.2	97.9	100.8	96.2	107.1

Table B1g: R&D industry level deflators

Industry			
year	X	Y	Z
1997	96	102.3	100.5
1998	99.3	97.6	95.3
1999	100	96.5	95.7
2000	100	100	100
2001	97.4	97.5	104.1
2002	96.2	101.8	101.8
2003	98.2	103.5	104.5